MiniBooNE

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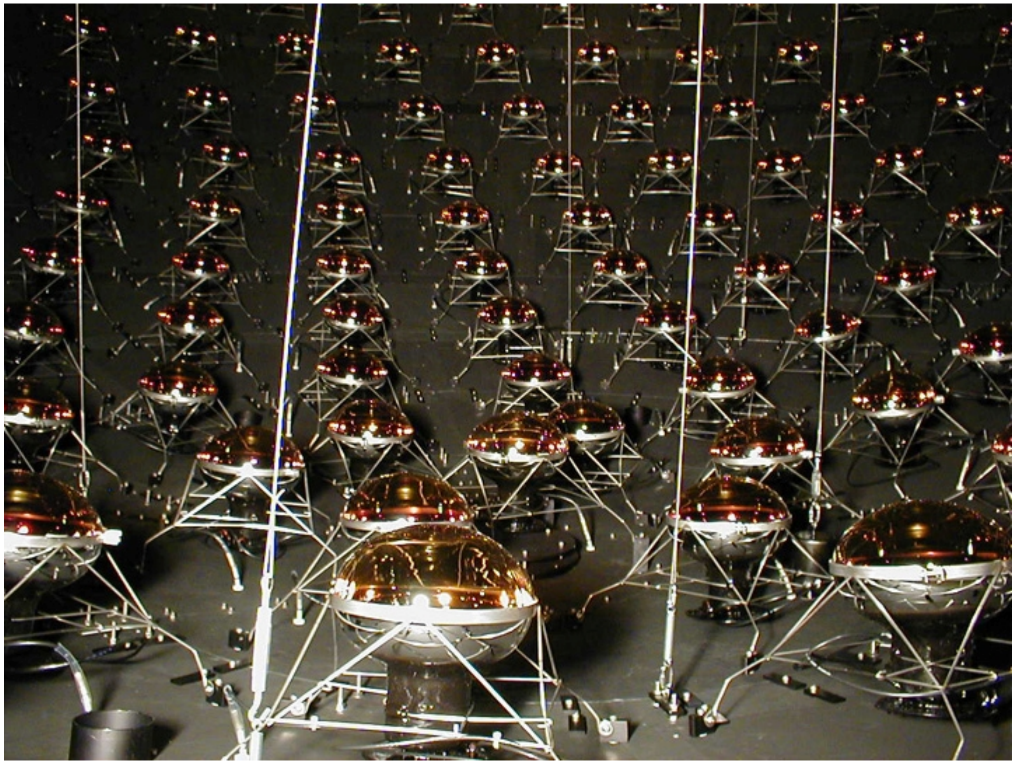
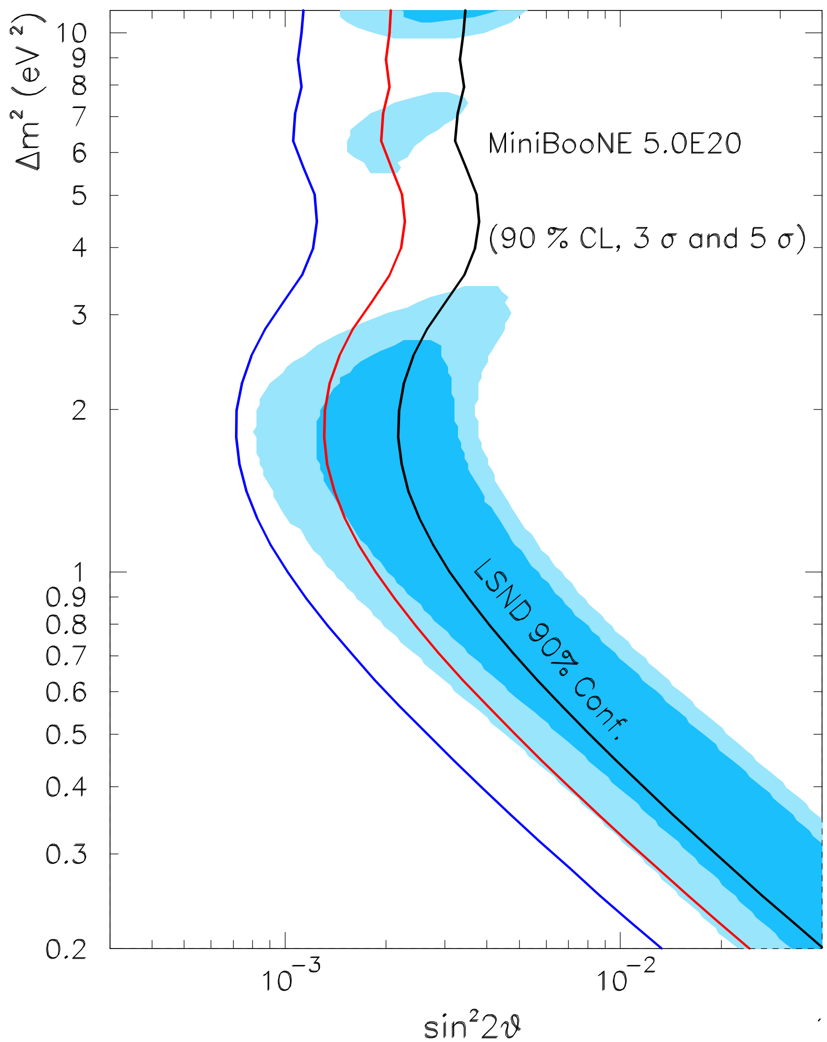


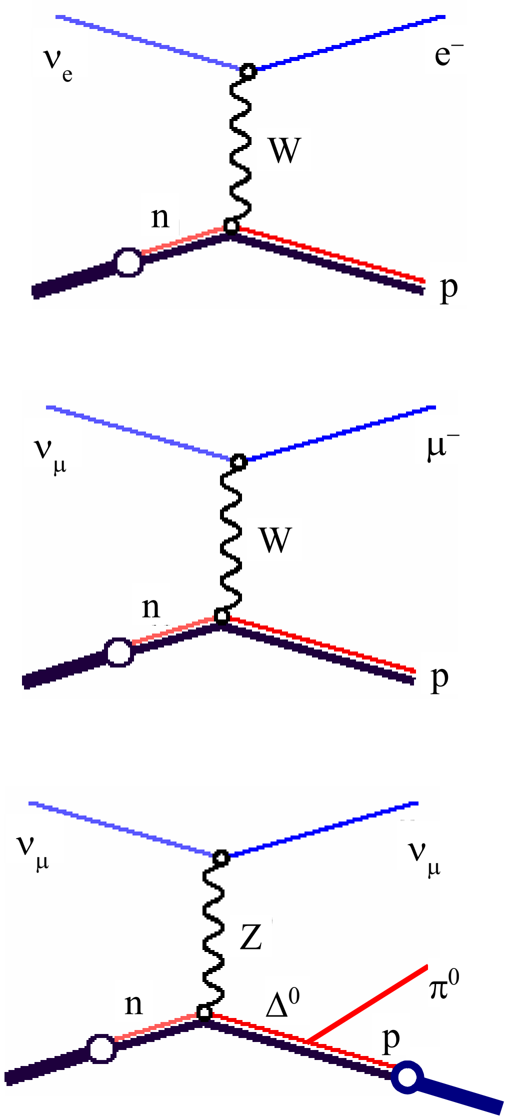
- Oscillation Analysis
- Issues of the Past Year
  - Normalization
  - Optical Model
  - π^0 MisIDs
- Summary
- Future

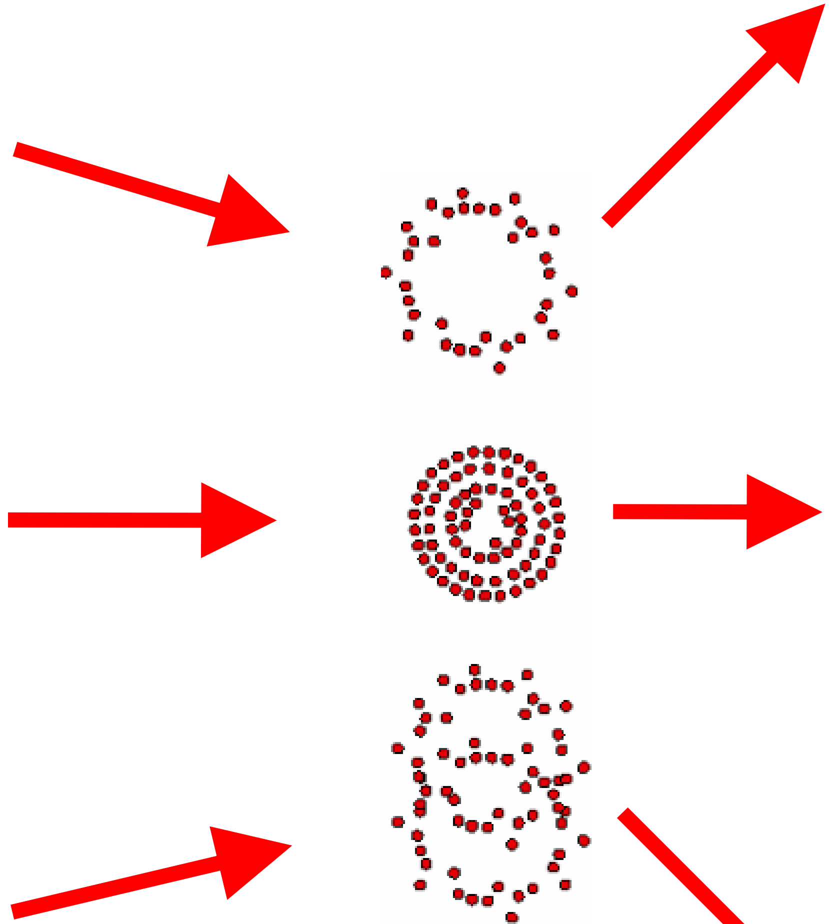


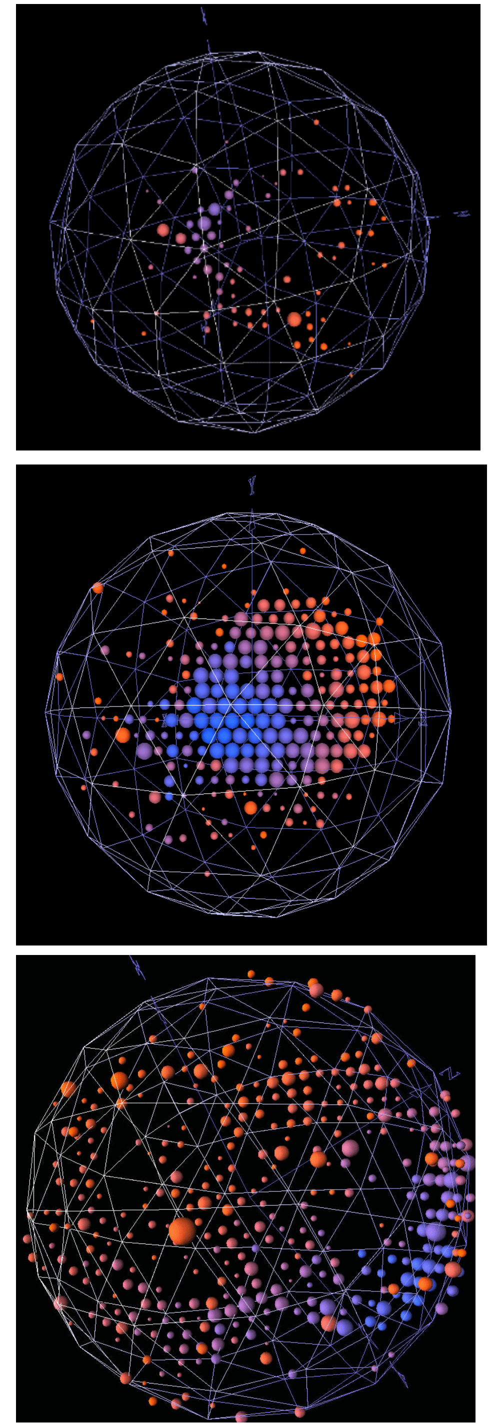
MiniBooNE Goal

- Search for ν_e appearance in a ν_μ beam at the ~0.3% level
  - L=540 m ~10x LSND
  - E~500 MeV ~10x LSND

Particle ID







- Identify electrons (and thus candidate ν_e events) from characteristic hit topology
- Non-neutrino background easily removed

Particle ID

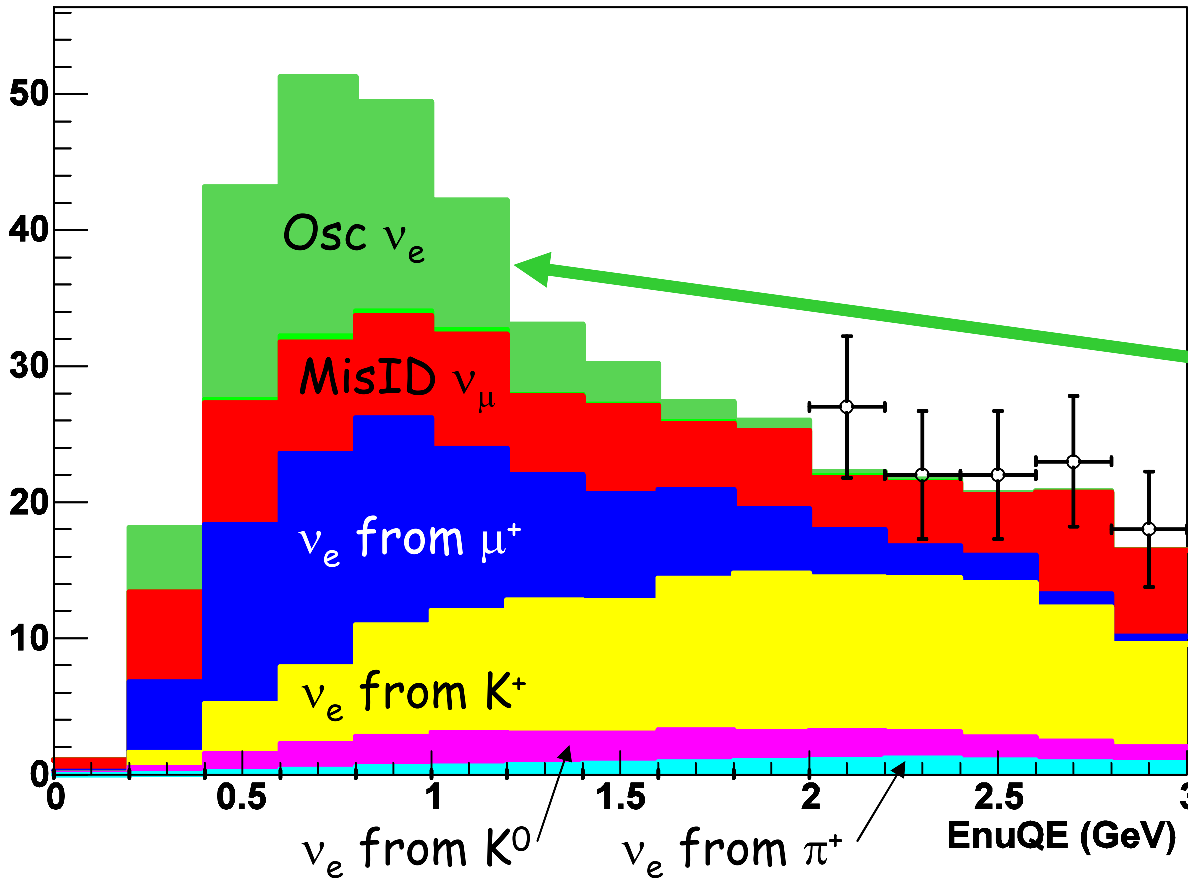
- To achieve good sensitivity the Particle ID must
  - Eliminate ~99.9% of all ν_μ CC interactions
  - Eliminate ~99% of all NC π^0 producing interactions
  - Maintain good (~30-60%) efficiency for ν_e interactions
- It achieves these goals
- Exploring parallel, complementary approaches
  - "Simple" cuts: easy to understand
  - Boosted decision trees: maximize sensitivity

Backgrounds

- Makeup of the backgrounds is different for the two particle ID approaches
  - Different balance between intrinsic ν_e and misIDed ν_μ
  - Important check that backgrounds are understood
- Backgrounds are determined from our own data using
  - ν_μ CCQE events for intrinsic ν_e from μ^+
  - Single π^0 events for π^0 misID
  - High energy ν_e events for intrinsic ν_e from K^+

Determining Backgrounds with MiniBooNE Data

Full data sample ~5.3 x 10^{20} POT

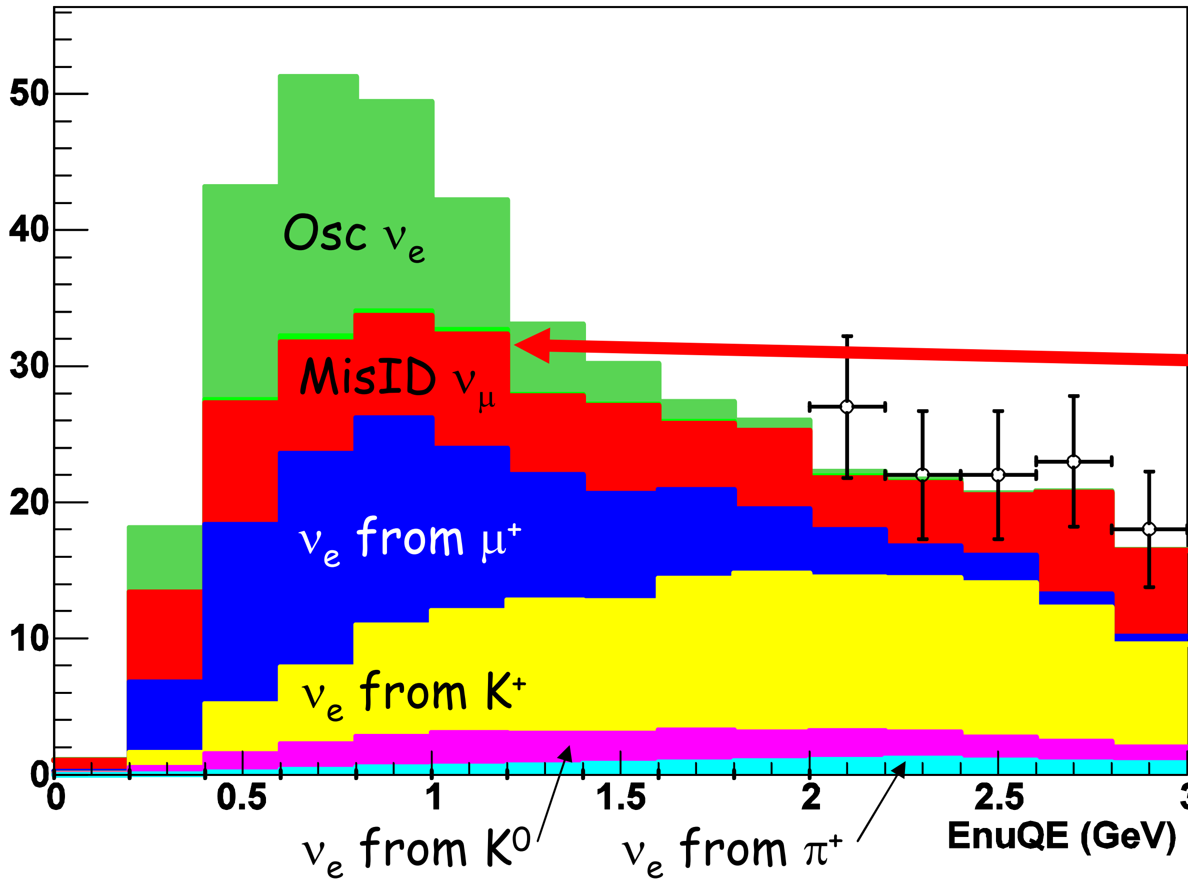


Osc ν_e

- Example oscillation signal
  - $\Delta m^2 = 1\ eV^2$
  - $SIN^2 2\theta = 0.004$
- Fit for excess as a function of reconstructed ν_e energy

Determining Backgrounds with MiniBooNE Data

Full data sample ~5.3 x 10^{20} POT

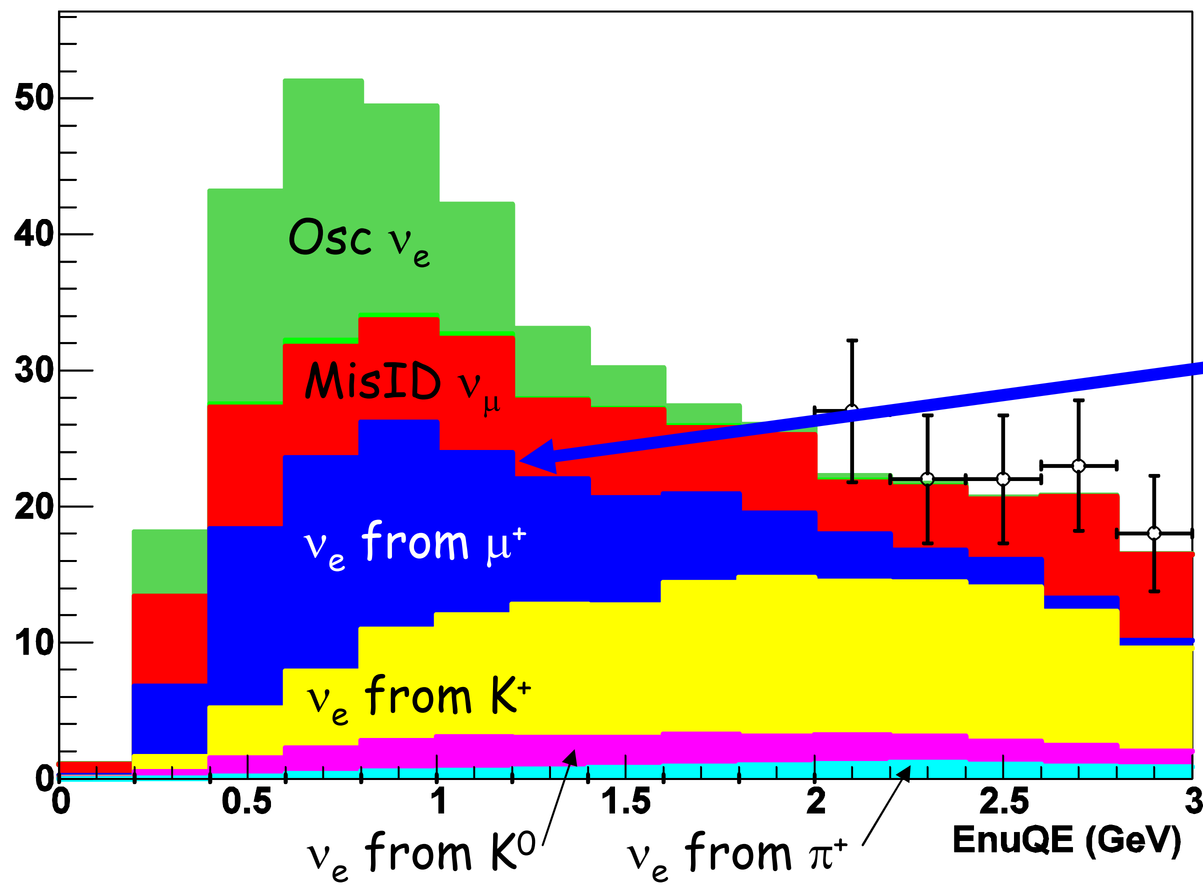


MisID ν_μ

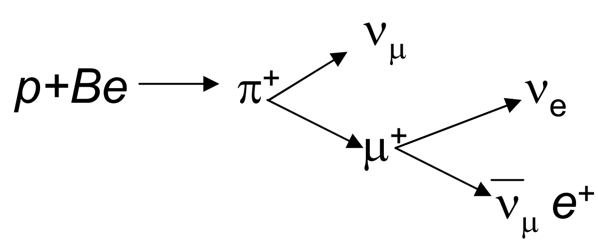
- of these……
- ~83% π^0
  - Only ~1% of π^0s are misIDed
  - Determined by clean π^0 measurement
- ~7% $\Delta\ \gamma$ decay
  - Use clean π^0 measurement to estimate Δ production
- ~10% other
  - Use ν_μ CCQE rate to normalize and MC for shape

Determining Backgrounds with MiniBooNE Data

Full data sample ~5.3 x 10^{20} POT



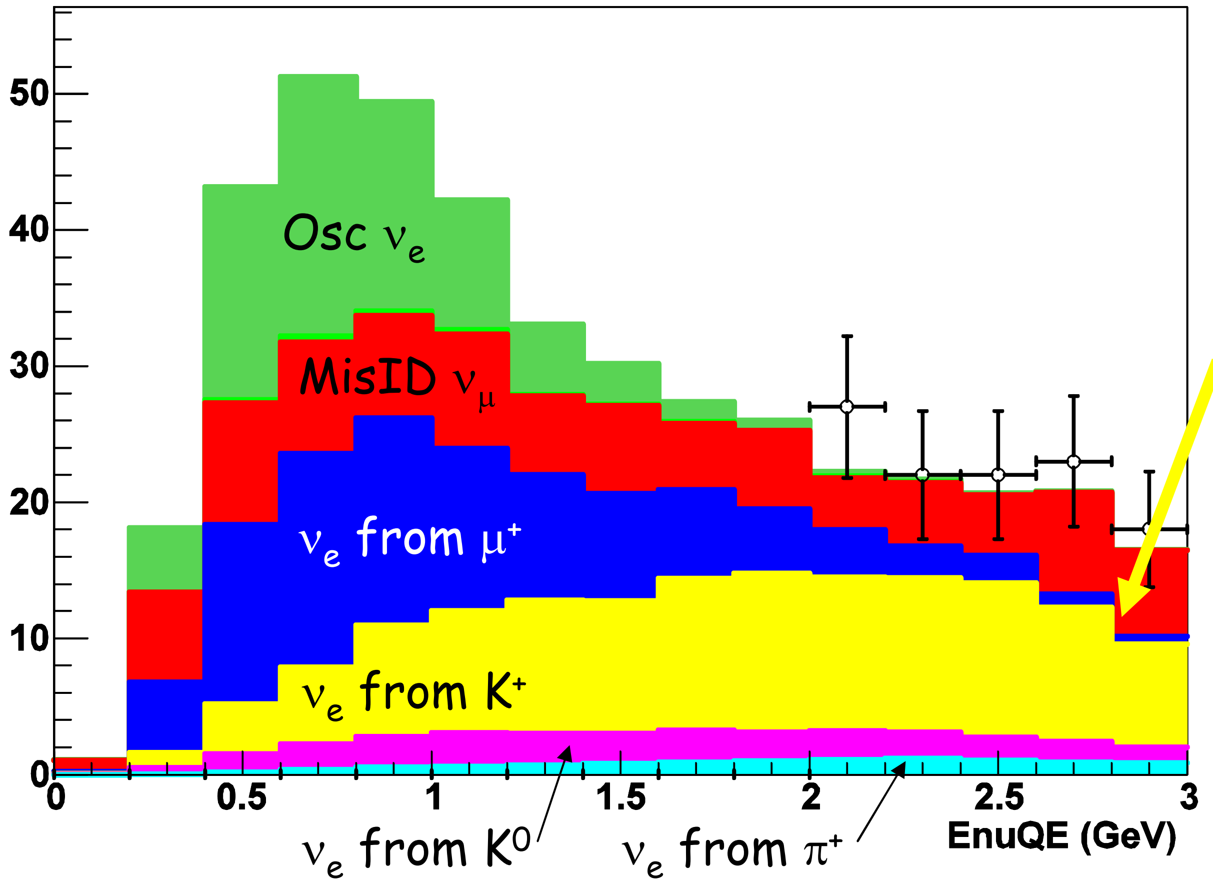
ν_e from μ^+



- Measured with ν_μ CCQE sample
  - Same parent π^+ kinematics
- Most important background
- Very highly constrained (a few percent)

Determining Backgrounds with MiniBooNE Data

Full data sample ~5.3 x 10^{20} POT

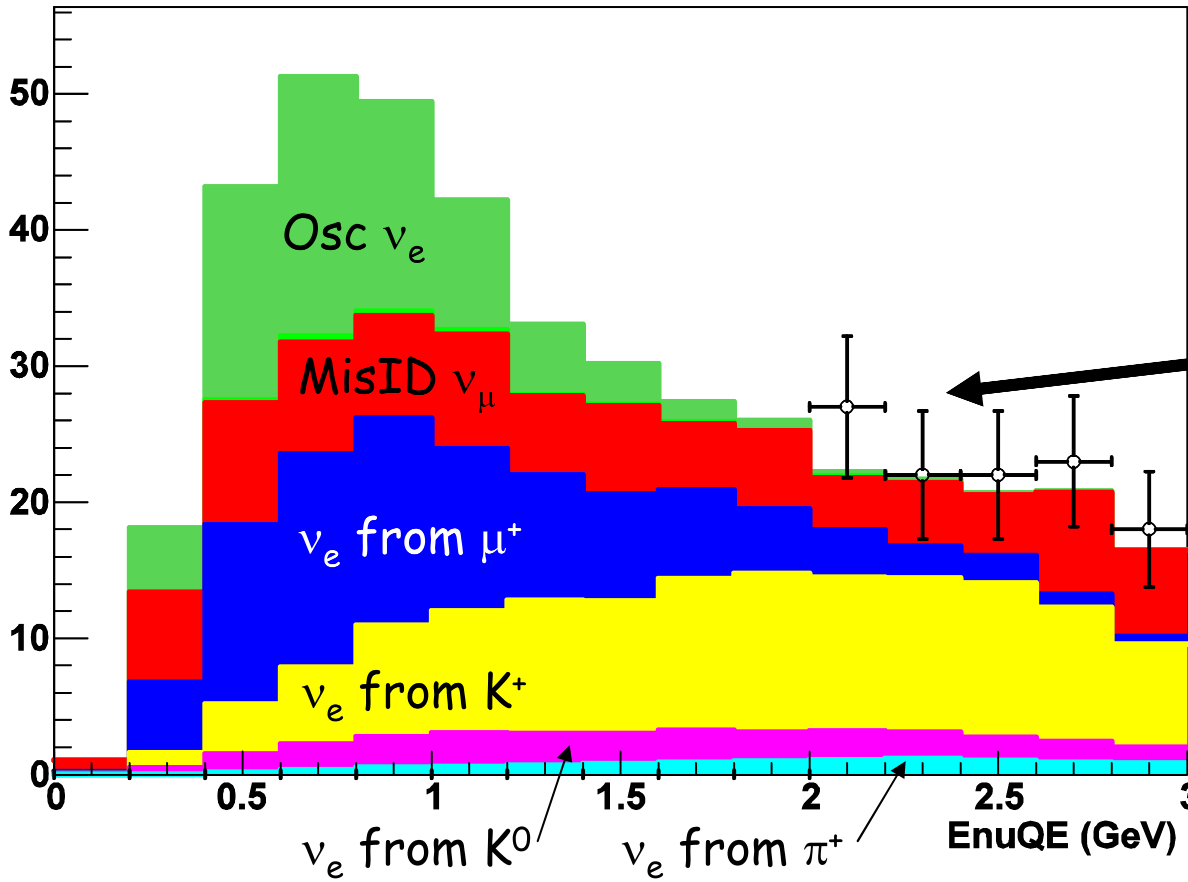


ν_e from K^+

- Use High energy ν_e and ν_μ to normalize
- Use kaon production data for shape
- Need to subtract off misIDs

Determining Backgrounds with MiniBooNE Data

Full data sample ~5.3 x 10^{20} POT



High energy ν_e data

- Events below ~1.5 GeV still in closed box (blind analysis)

Issues Of the Past Year

- Most of the analysis effort over the last year has gone into
  - Normalization
  - Optical Model
  - π^0 MisIDs
- Each is a significant hurdle that has been overcome

Issues of the Past Year: Normalization

- The MiniBooNE Run Plan reported we were seeing ~1.5 times as many events as the Monte Carlo predicted
  - For an inclusive ν event sample
- This normalization difference is now ~1.2
- Major changes in rate prediction since Run Plan (not complete list) ...

-3.5%	from better ν cross-section modeling
+17.5%	from better modeling of incoming proton beam
+5.2%	from CCQE cross-section tuning (M_A extraction)
-6.0%	from better modeling of secondary beam interactions
+16.2%	from HARP π^+ measurement + horn current + better modeling of primary proton interactions

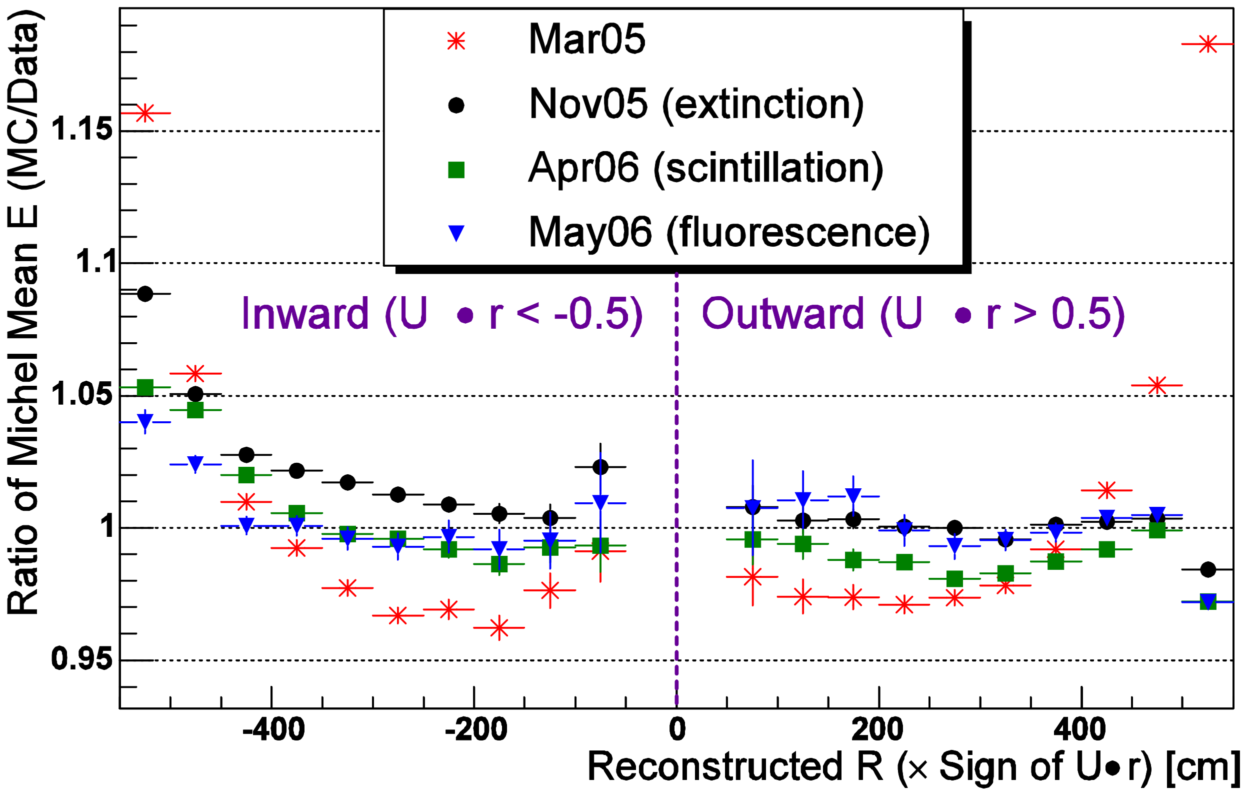
- After a huge amount of cross-checking the agreement between data and MC ν rates is now far less of an issue

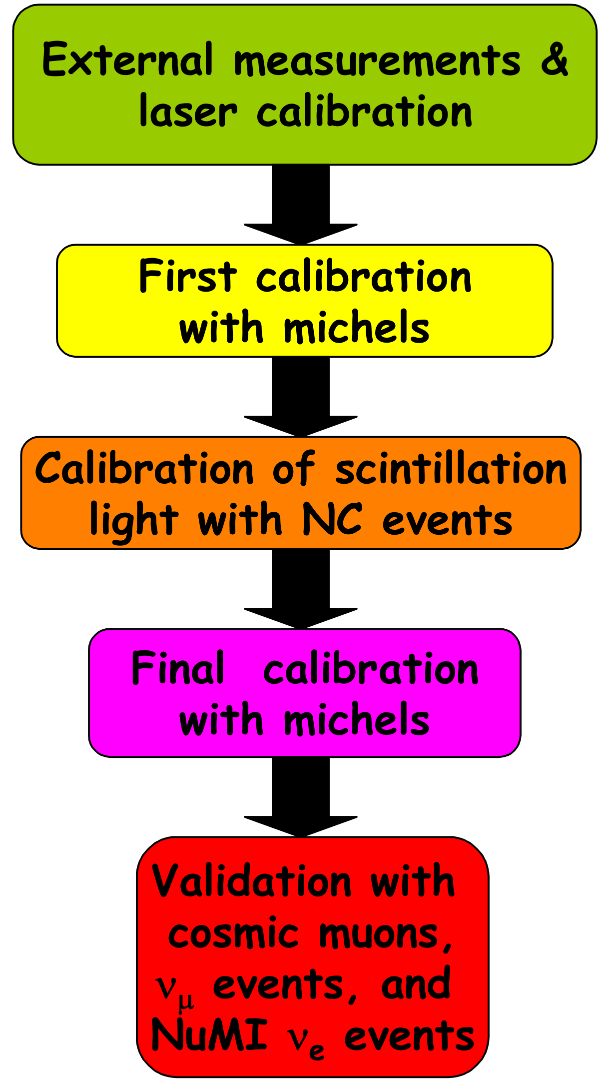
Issues of the Past Year: Optical Model

- Two Key features of MiniBooNE
  - Trying to do very precise particle ID to identify a possible ~0.3% signal
  - Several calibration sources, but none with the perfect properties (e.g. no 1 GeV electron gun)
- The approach must therefore be…
  - Use the available calibration sources (Michel electrons, laser, etc)
  - Have a very well tuned MC to extrapolate from what the calibration sources look like to what the signal and background look like
- Therefore…
  - Need an "optical model" that matches data very well
  - Optical Model = model for how light is created, propagated, and detected in MiniBooNE

Issues of the Past Year: Optical Model

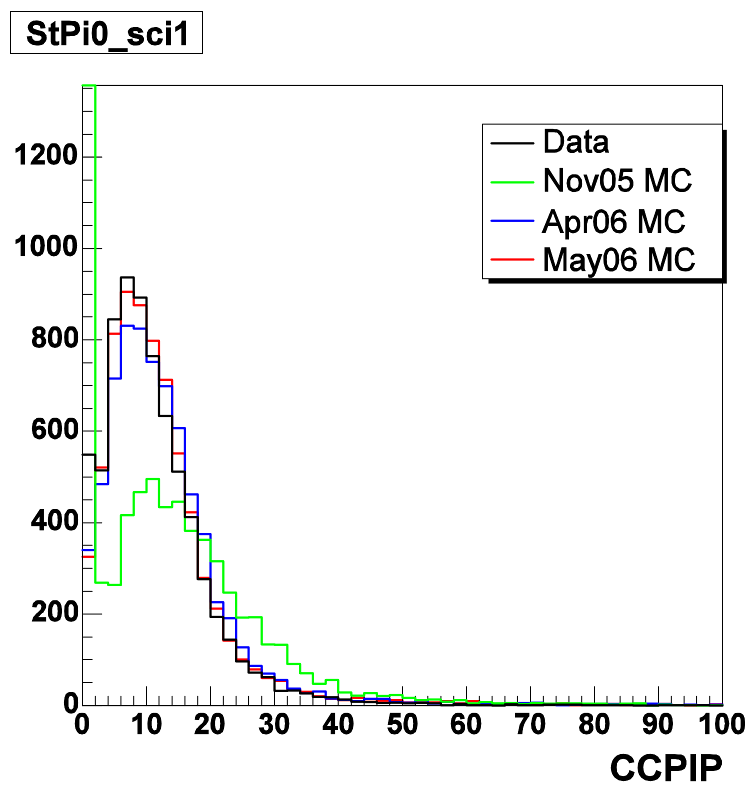
- Stepwise approach to tuning the optical model

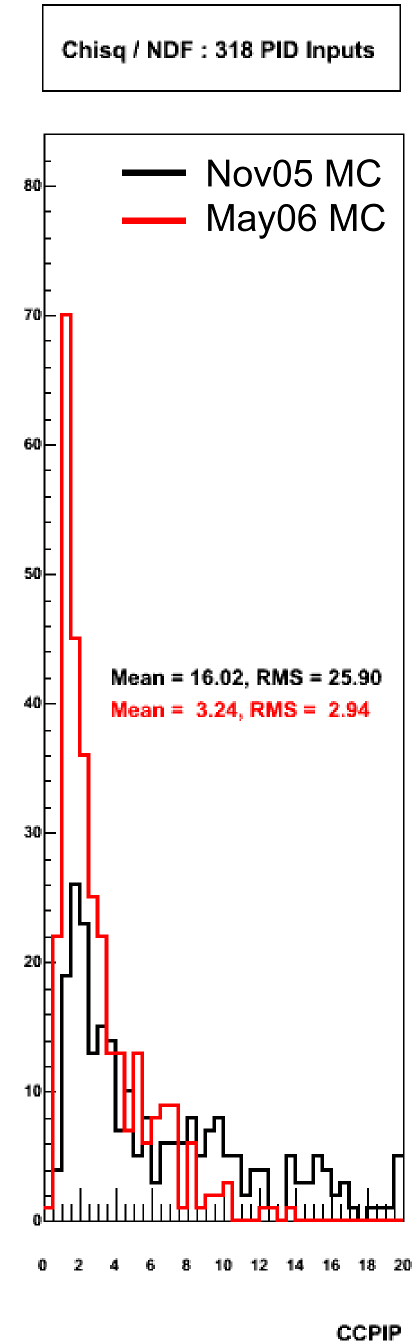




Issues of the Past Year: Optical Model

- Many variables are potentially useful in analyses
- Optical Model improvement measured by data/MC agreement in these variables
- Huge gains in data/MC agreement





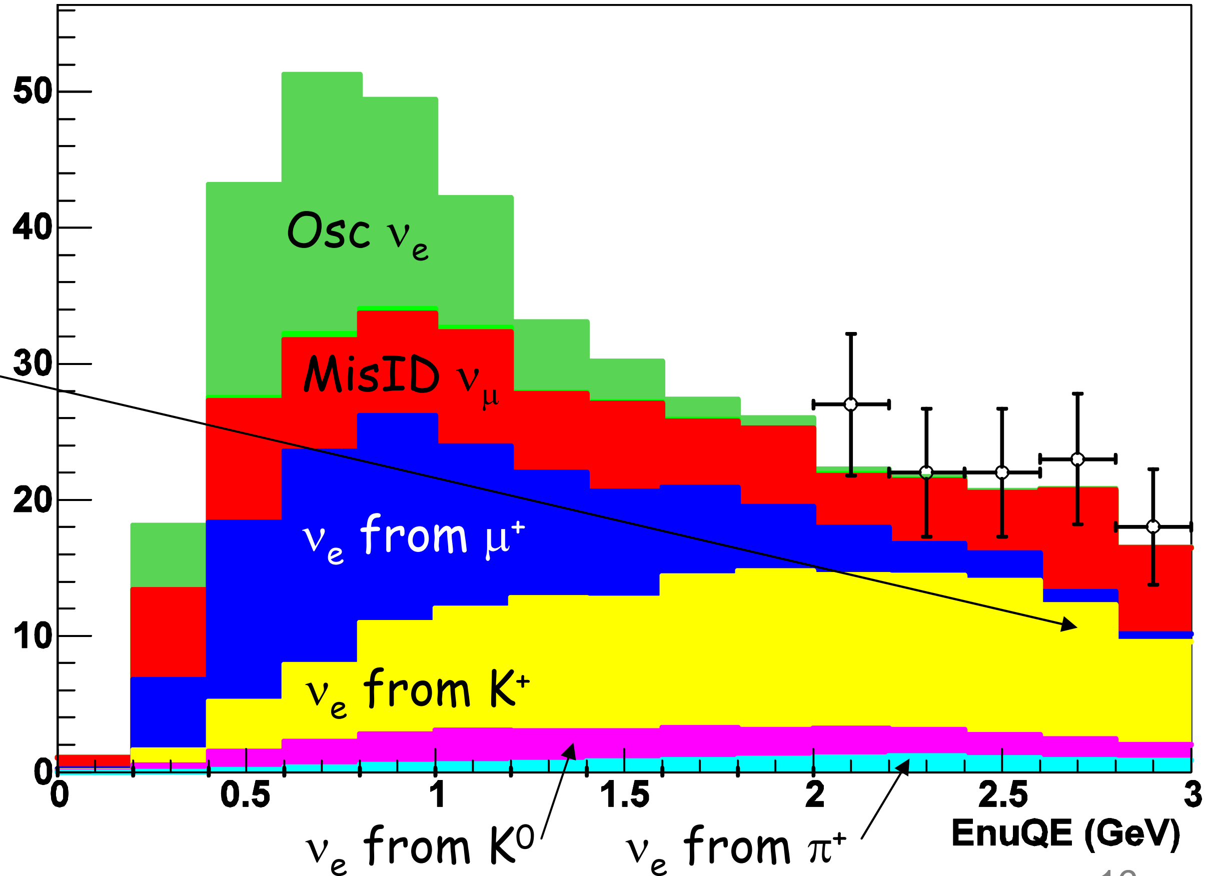
Issues of the Past Year: π^0 MisIDs

- About 83% of all MisID background comes from single π^0 events
- Use cleanly identified π^0s to measure the π^0 rate as a function of π^0 momentum

Need to get to high π^0 momentum to enable measurement of high energy ν_e background from K^+

Old π^0 reconstruction could not do this

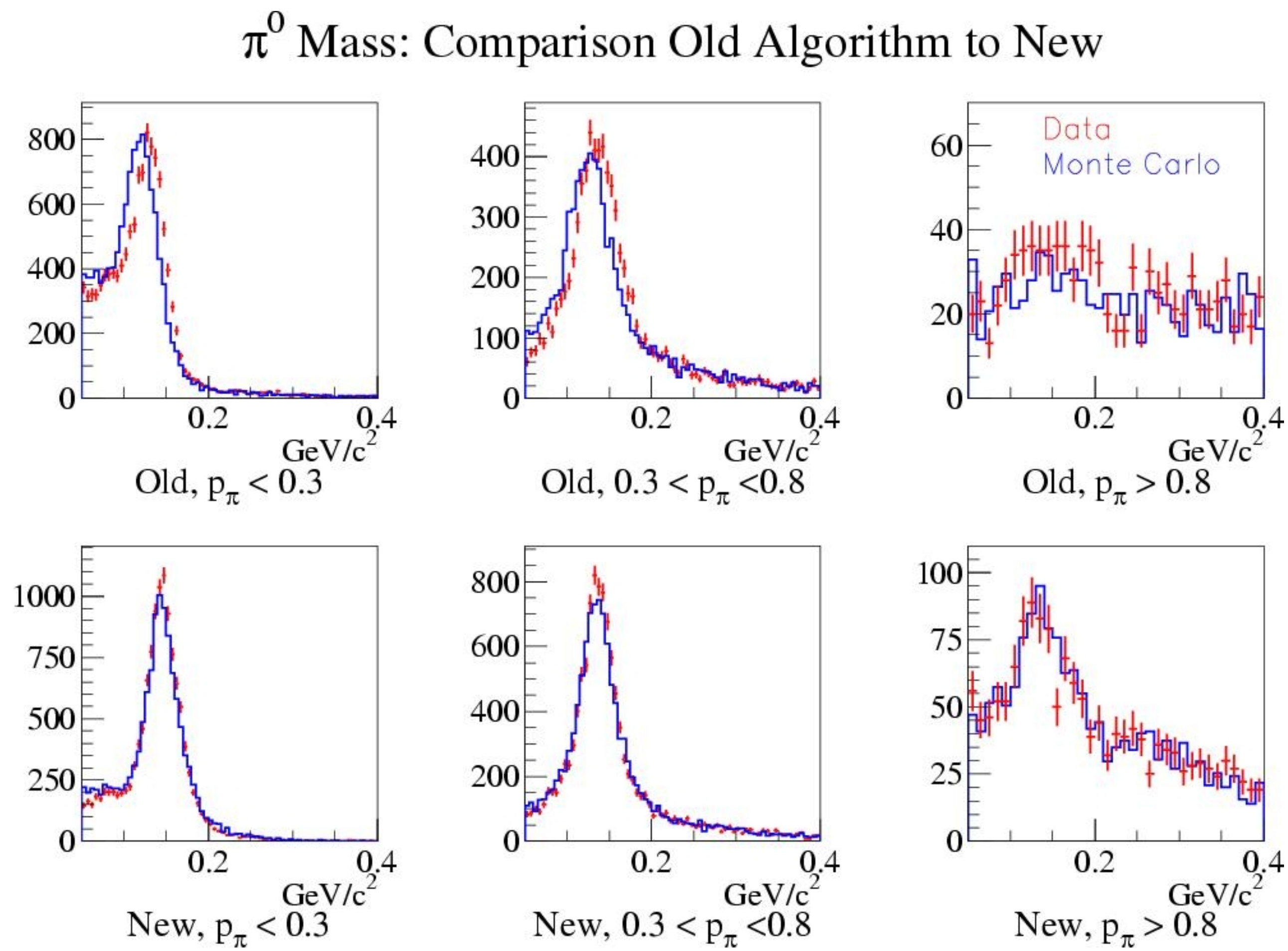
Have developed a new π^0 fitter that can go to high momentum and has better π^0 efficiency and purity



Issues of the Past Year: π^0 MisIDs

New π^0 fitter can make π^0 yield measurements up to the ~1.5 GeV level needed to get at the ν_es from K^+

This is an ongoing analysis – not yet complete



Summary

- Over the past year the major hurdles have been crossed
  - Much more accurate prediction of rate – data/MC ~1.2
  - Optical Model probably now good enough (more checks needed)
  - Analysis for π^0 misID measurement largely in place
- Still a lot of work to do – but the way forward is clear
- On track for a result as soon as this summer

The Future

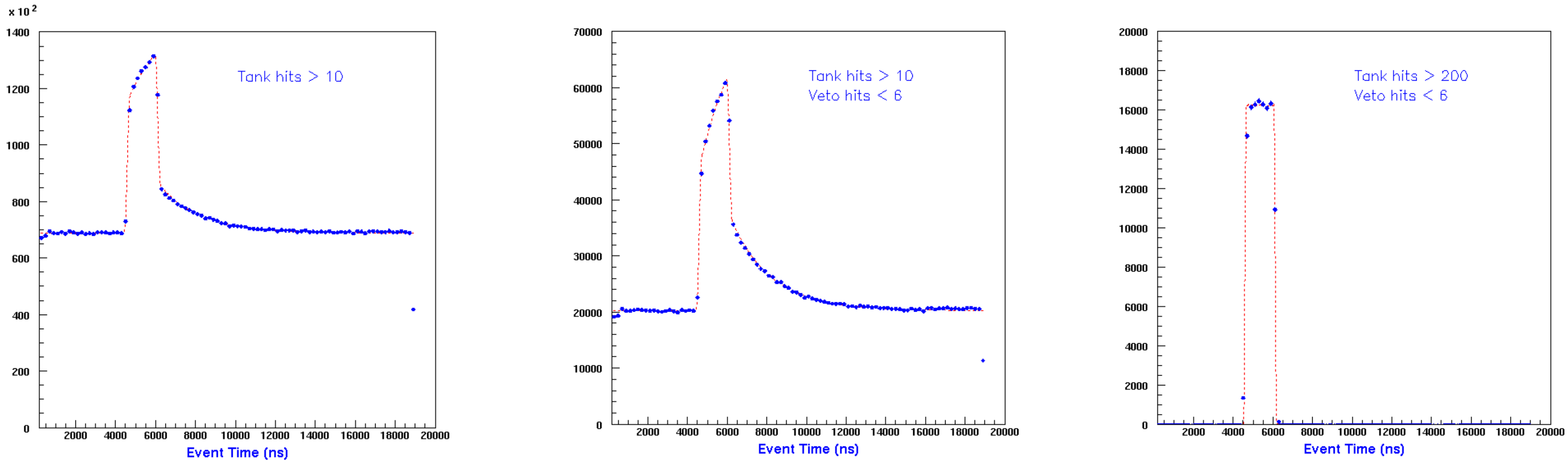
- Ran in anti-neutrino mode January 2006 to shutdown
- Will continue in anti-neutrino mode after shutdown
  - First ever anti-neutrino measurements in this energy region

- SciBooNE experiment, at a near location in the beamline, will start in late 2006 (see SciBooNE talk)

- Possibility to build additional detectors closer or farther away (BooNE)
  - MiniBooNE clone or new technology (e.g. LAr)
  - MiniBooNE result will guide location
    - ~2km detector for low Δm^2
    - ~0.2km detector for high Δm^2

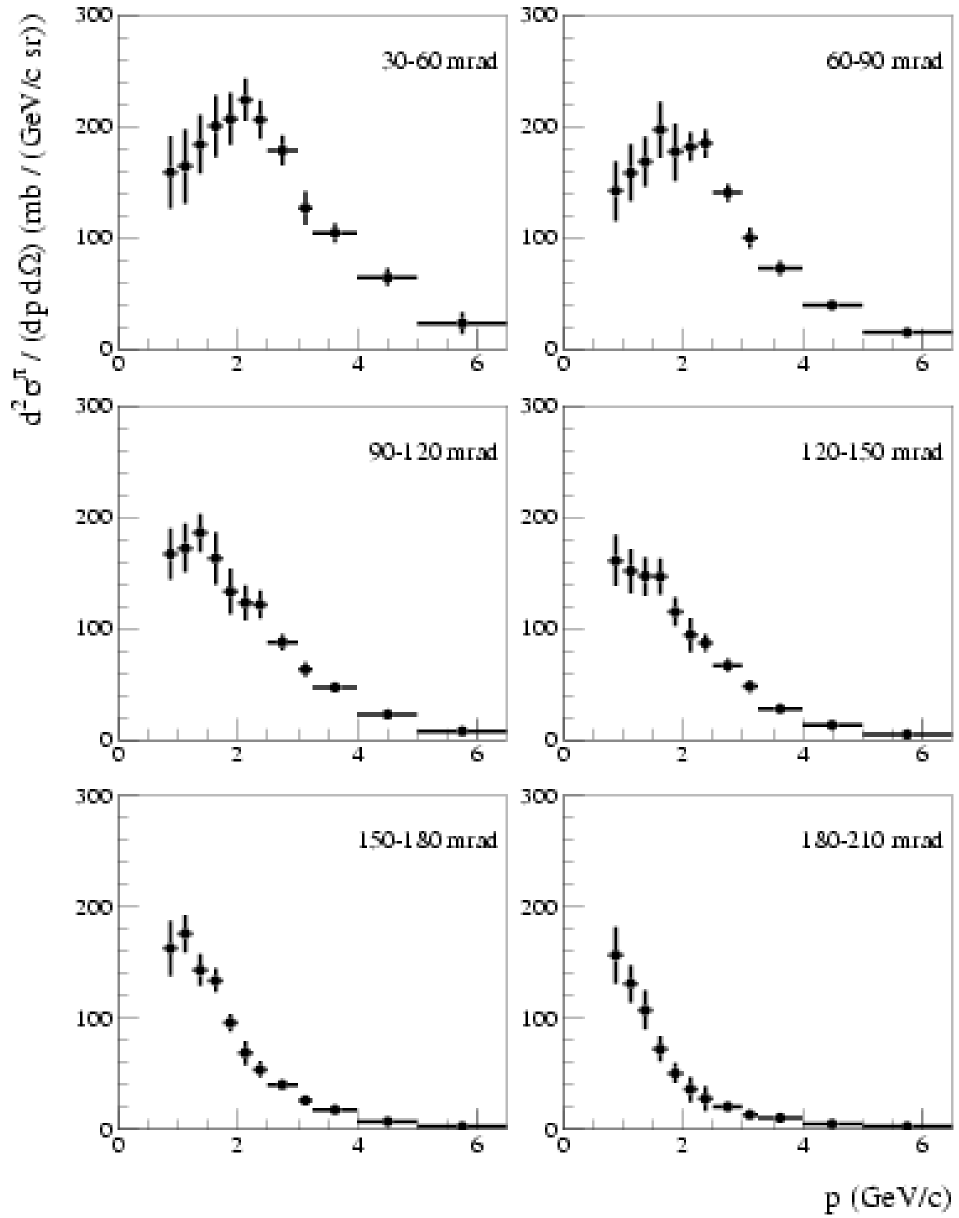
Backups

Neutrino Candidates



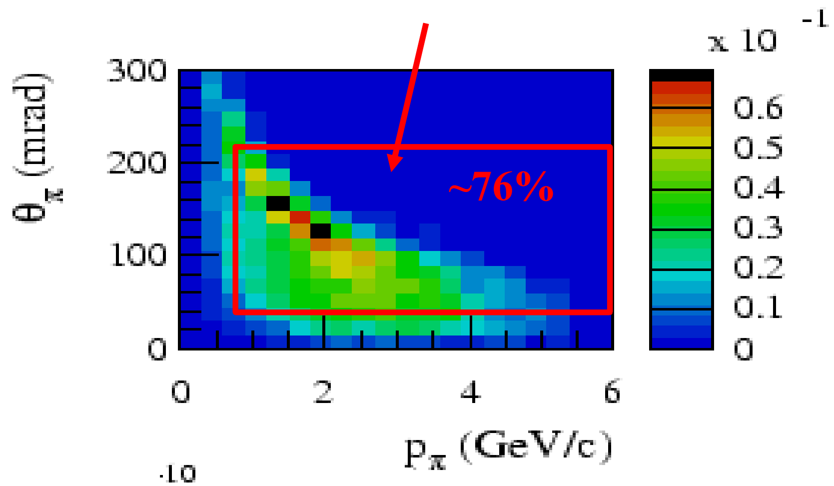
- DAQ triggered on beam from Booster
- ν pulse through detector lasts 1.6 μs
- By requiring tank activity and no veto activity the non-neutrino backgrounds become negligible

proton->Be collisions at 8.9 GeV/c



piplus cross section with full statistical plus systematic errors shown (except the 4% normalization error)

$0.75 < p_\pi < 6.5$ GeV/c
$30 < \theta_\pi < 210$ mrad



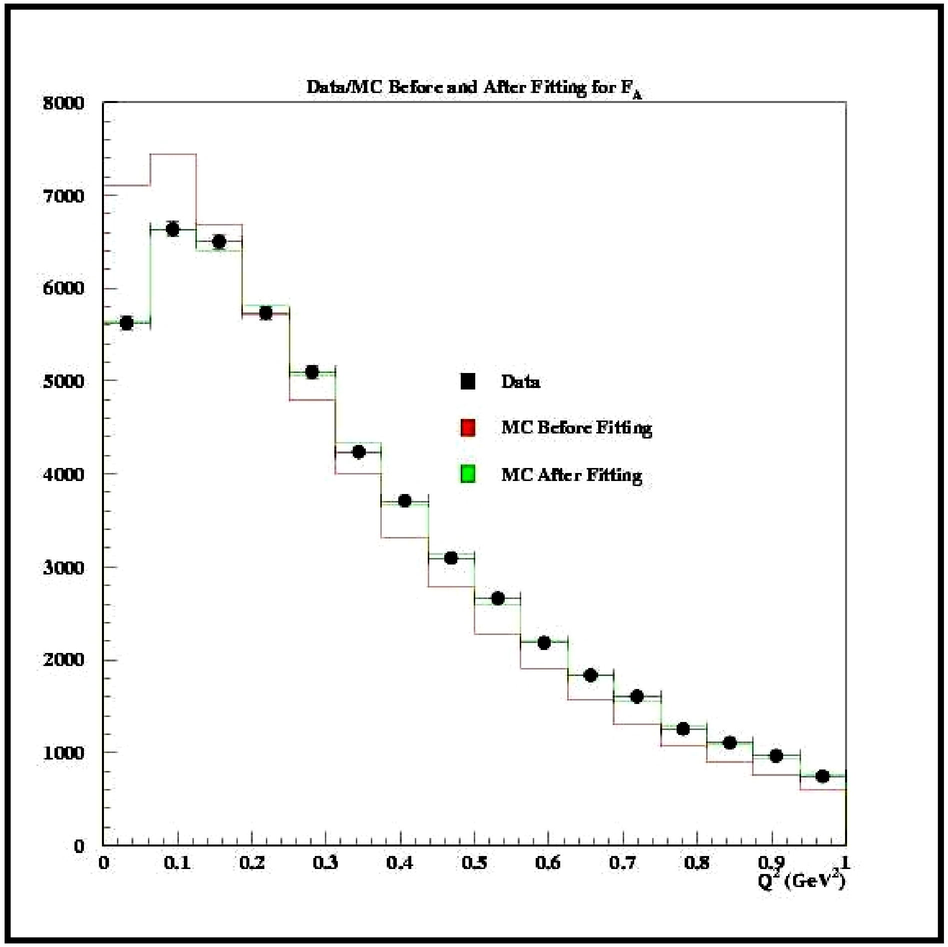
Momentum and angular distribution of pions decaying to a neutrino that passes through the MB detector.

Low Q^2 & MiniBooNE QE Model

- perform shape fit to MiniBooNE QE dN/dQ^2
  (~60,000 QE events after cuts)

- fit for:
  - Fermi Gas model pars (E_B,p_F)
  - axial mass, M_A
  - and background fraction, B_F

- best shape fit yields "effective parameters":
  - M_A=1.24 GeV
  - E_B = 34 MeV
  - p_F = 246 MeV
  - B_F = 0.7

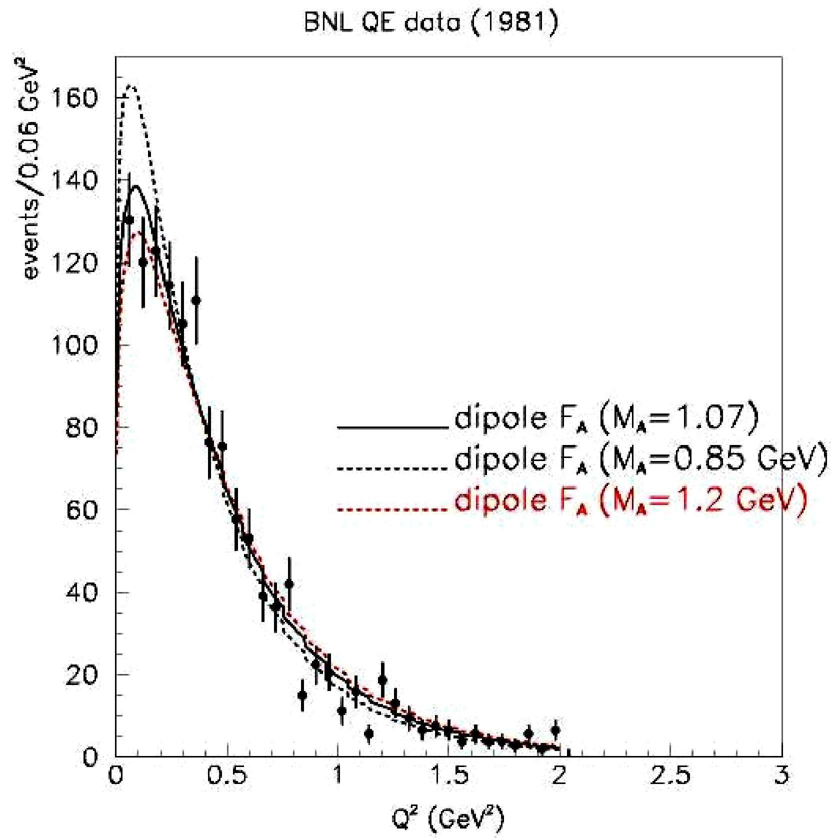


(J. Monroe)

Past ν Data

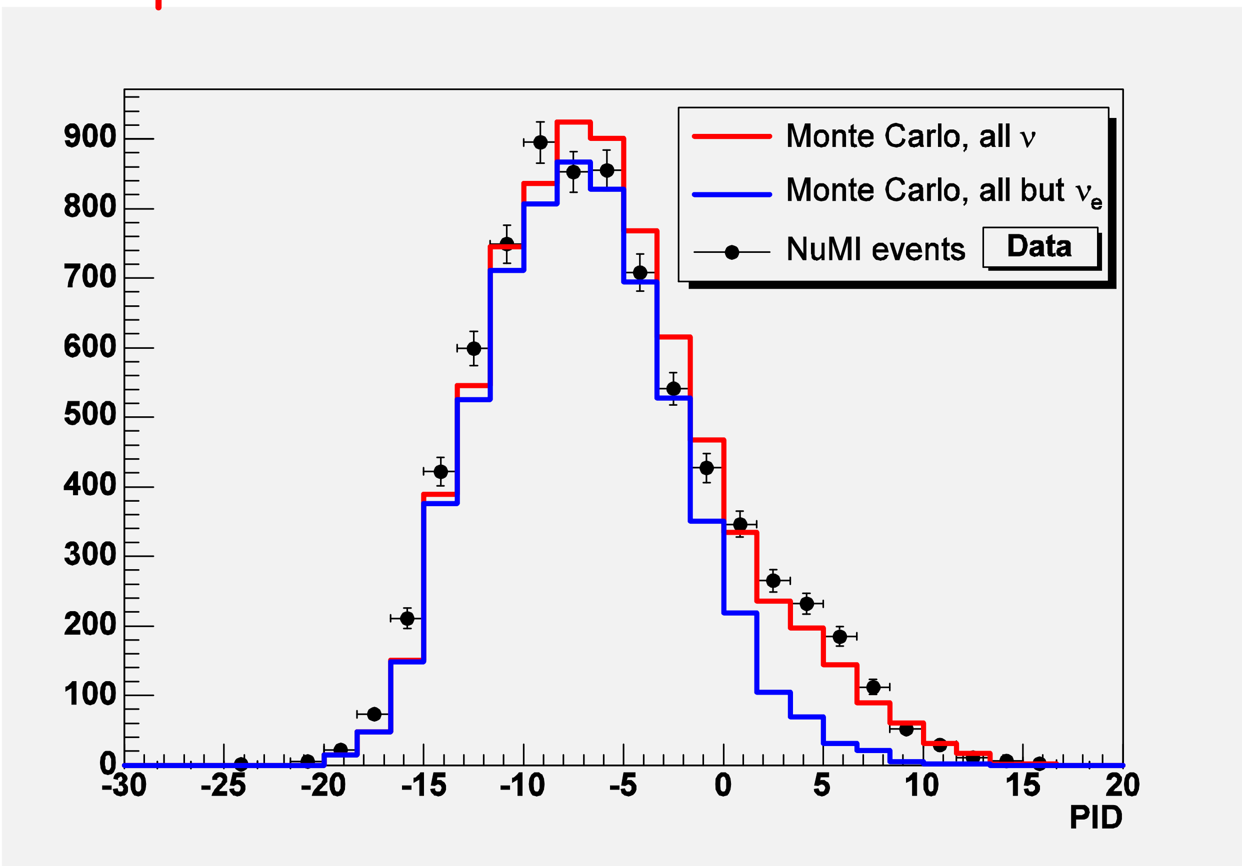
- not clear that past QE neutrino data necessarily rules out a larger value for M_A

- example: BNL bubble chamber data and $d\sigma/dQ^2$ predictions with different M_A assumptions



Checking Particle ID with NuMI Events

- Because of the off-axis angle, the beam at MiniBooNE from NuMI is significantly enhanced in ν_es from K^+
- Enables a powerful check on the Particle ID



And in the future…